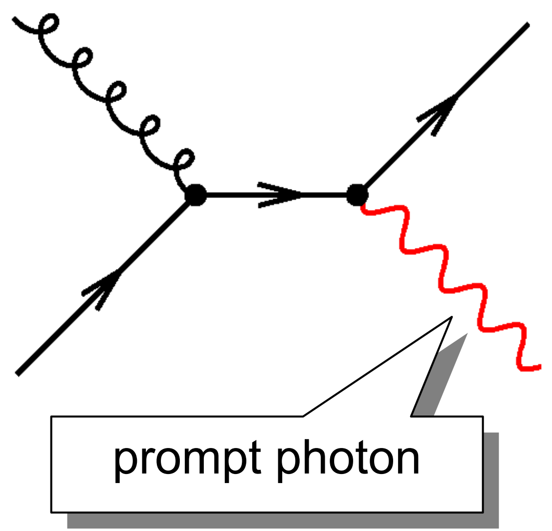
Prompt Photon Production at HERA and LEP

ICHEP 2004, Beijing

Thomas Kluge, DESY

on behalf of the H1, OPAL and ZEUS Collaborations

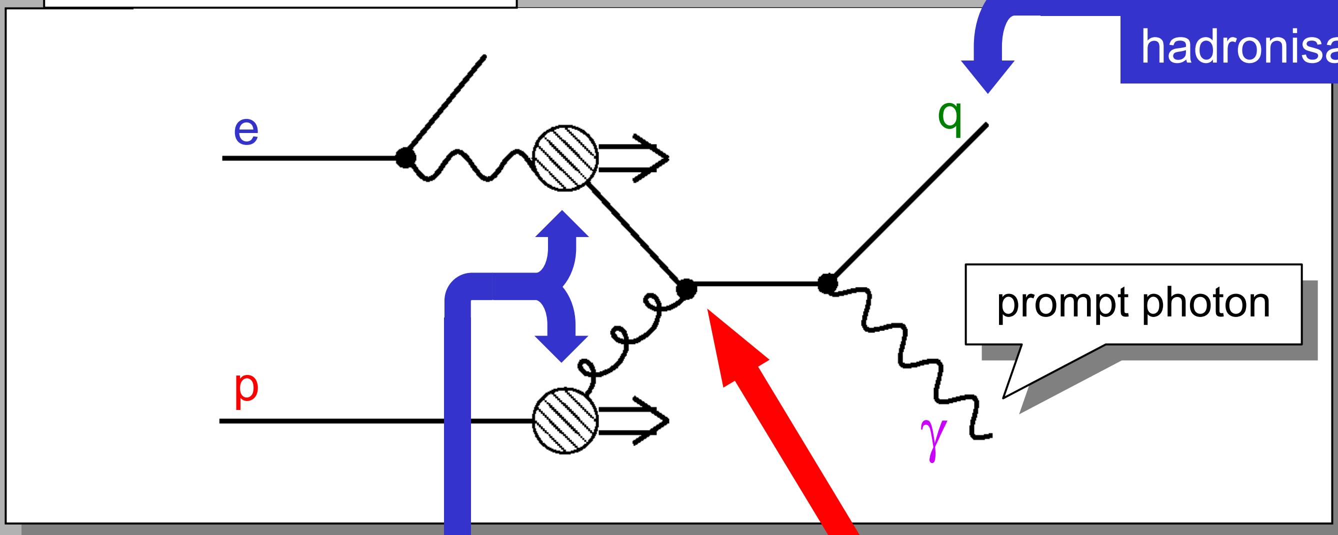
- Introduction / Motivation
- Photon Identification
- Results
  - – Inclusive Prompt Photons
  - – Prompt Photons together with a Jet
- Conclusion / Summary



"Test QCD by measuring photons"

Prompt Photons and QCD

An example (HERA)



soft QCD

hadronisation models

soft QCD

parametrised in p.d.f.

hard QCD

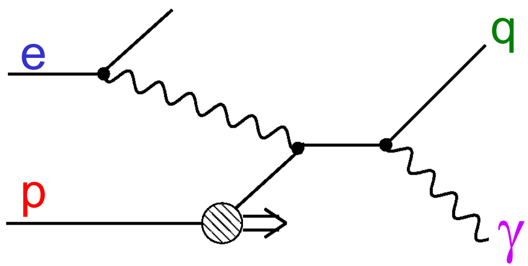
matrix elements up to NLO in α_s

- Prompt photon: small hadronisation uncertainty, good energy measurement!
- Two signatures are investigated
  1) isolated photon (inclusive)
  2) isolated photon + at least one jet (E_T > 3-5 GeV)

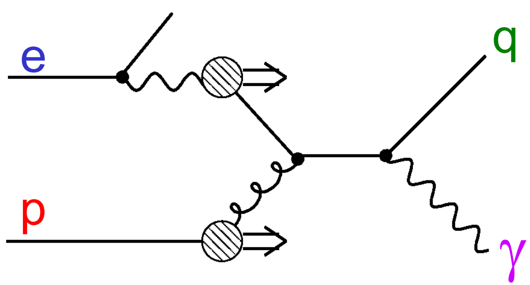
Production of Prompt Photons

electron proton collisions at HERA

direct photoproduction & deep inelastic scattering

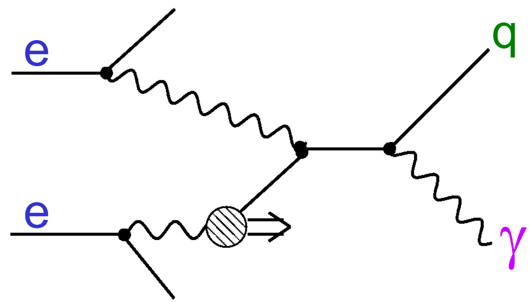


resolved photoproduction

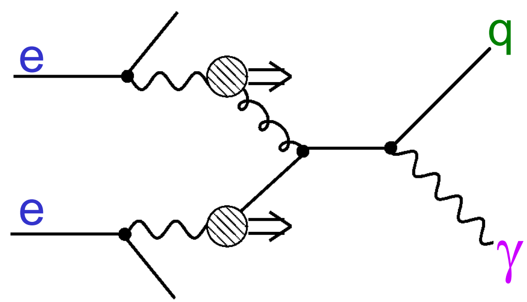


photon photon collisions at LEP

single resolved process



double resolved process



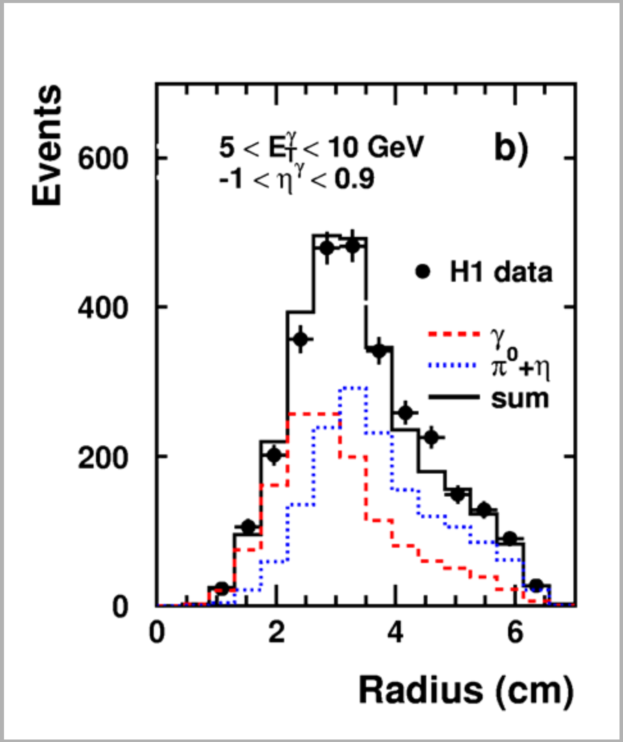
-  marks a remnant, made of low p_T particles
- direct/single resolved (resolved/double resolved) both present in data
- …there are more (higher order) diagrams

Some details on photon identification….

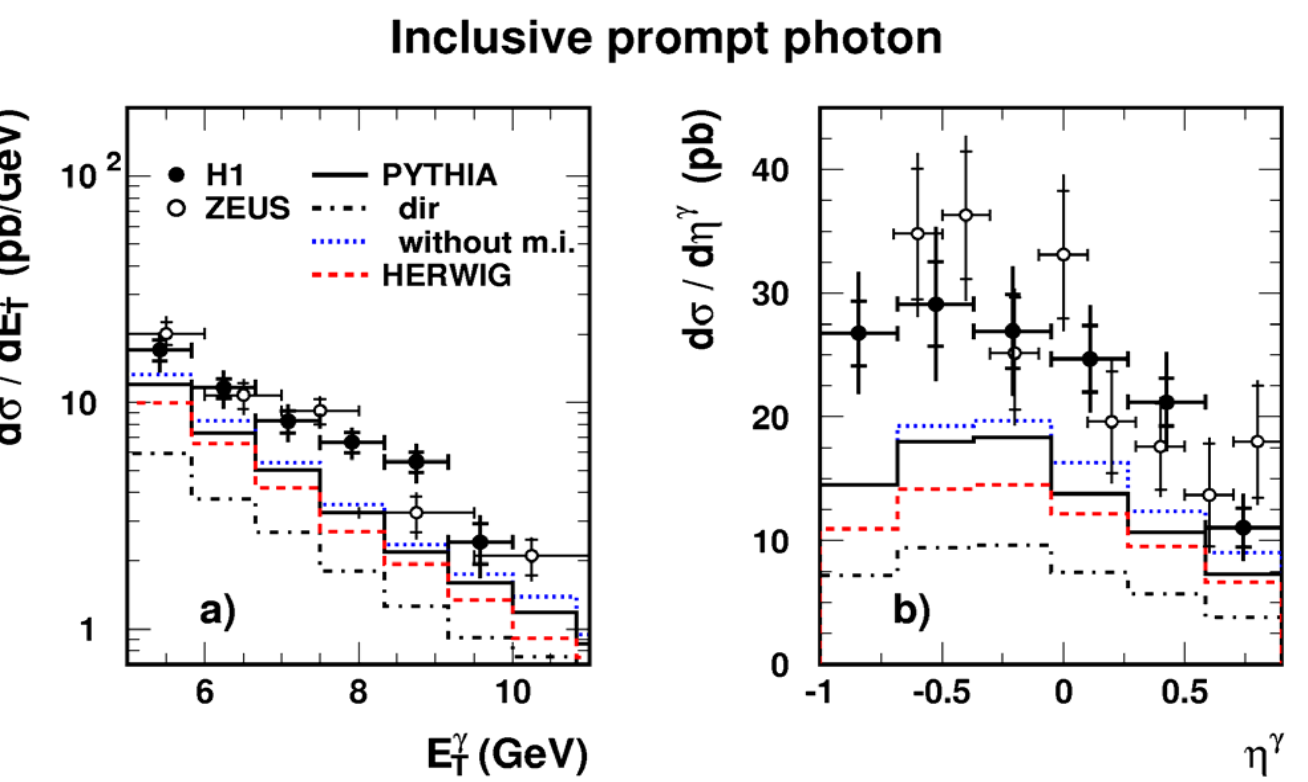
1. Basic γ selection: electromagnetic cluster, with no associated track
   Problem: large background of $\pi^0 \rightarrow \gamma\gamma$ and $\eta \rightarrow \gamma\gamma$

2. Require isolation cone: veto energy nearby the photon candidate
   Problem: sensitive to energy deposits from multiple interactions (m.i.)

3. Perform a shower shape analysis: single photons are more compact
   -> Fit signal/background ratio for any result bin (independent of MC background rate!)



Inclusive Prompt Photons in ep Photoproduction (HERA)



$142 < W < 266$ GeV

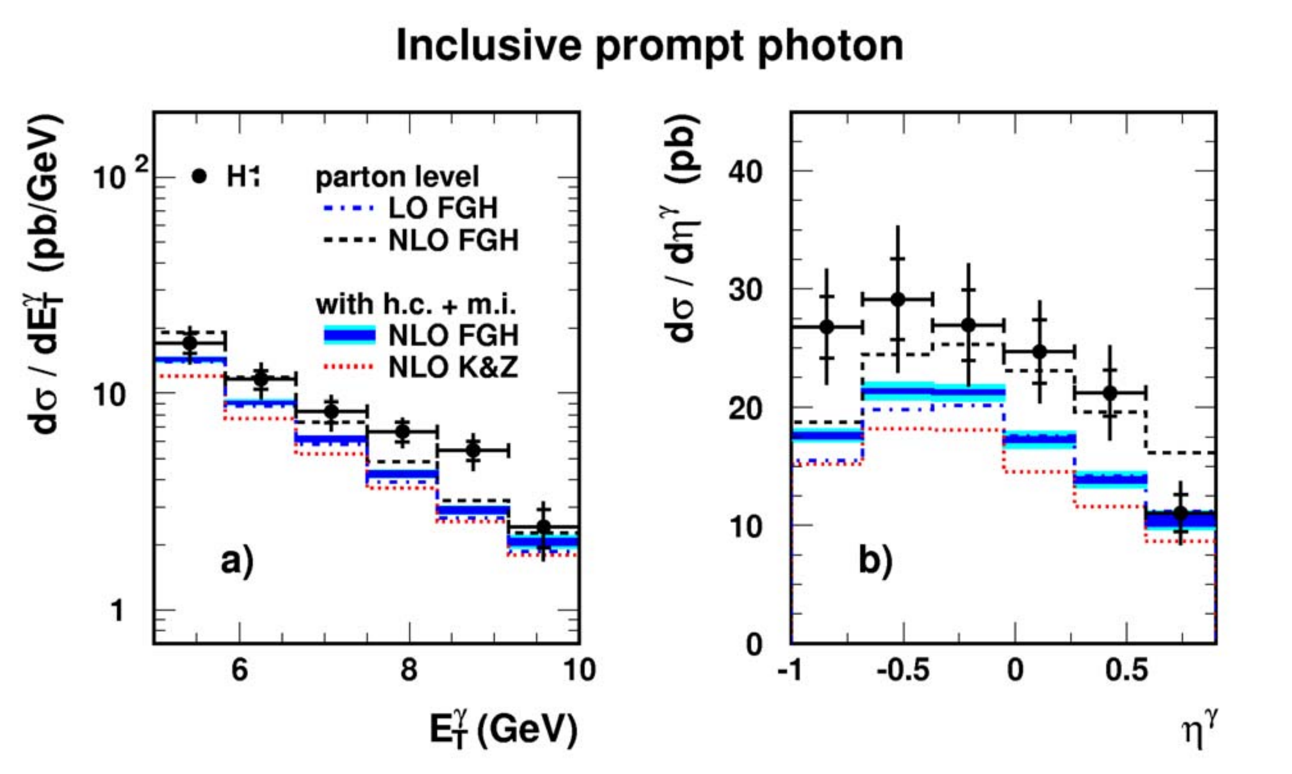
$Q^2 < 1 GeV^2$

$\mathscr{L}_{int} = 105\ pb^{-1}$

Comparison with PYTHIA and HERWIG event generators

- H1 and ZEUS data consistent within errors
- MC: shape OK but normalisation low by ~40-50%
  : direct exchanged γ makes up less than ½ of the cross section
- Multiple interactions spoil isolation cut -> reduced cross section

Inclusive Prompt Photons in ep Photoproduction (HERA)



$142 < W < 266$ GeV

$Q^2 < 1 GeV^2$

$\mathscr{L}_{int} = 105\ pb^{-1}$

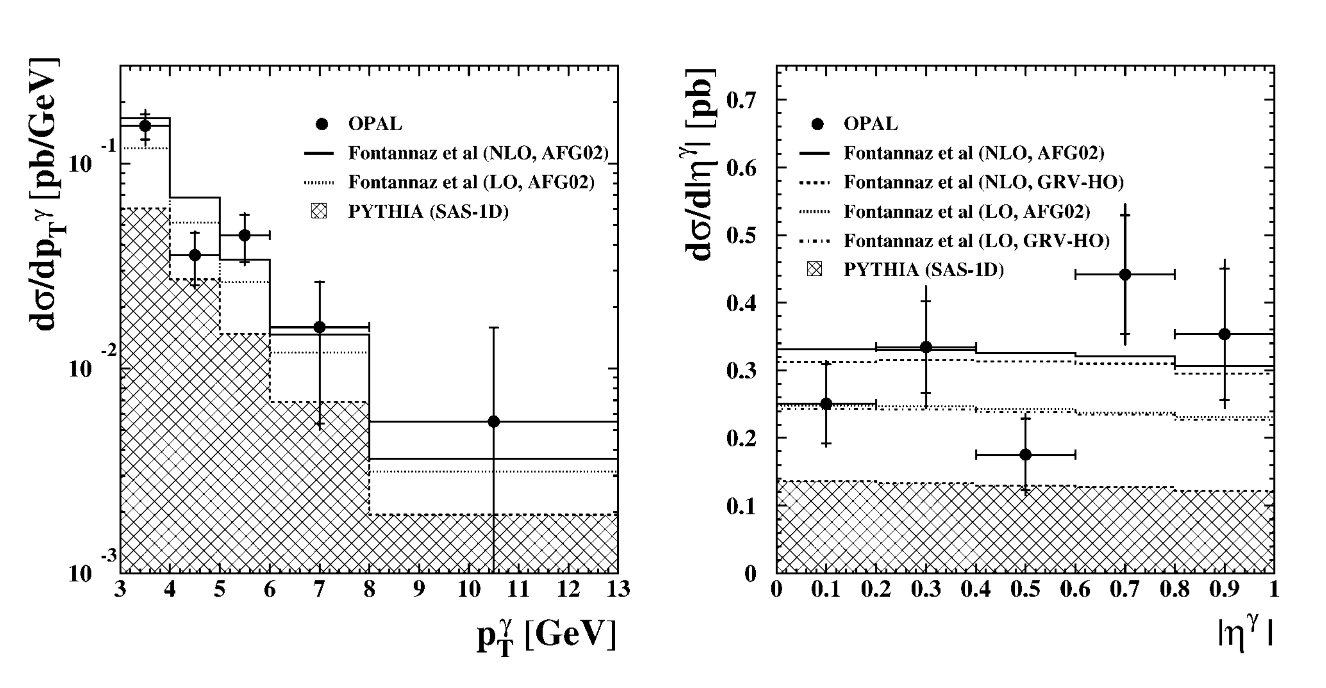
Comparison with NLO pQCD:

Fontanaz, Guillet, Heinrich (FGH)

Krawczyk, Zembruski(K&Z)

- Reasonable description by NLO calculations on parton level
- After corrections for hadronisation and multiple interactions: normalisation 30-40% below the data

Inclusive Prompt Photons in Photon-Photon Collisions (LEP)



$\langle s_{ee}\rangle^2 = (197\ \text{GeV})^2$

$Q^2 < 10\ \text{GeV}^2$

$\mathcal{L}_{int} = 649\ \text{pb}^{-1}$

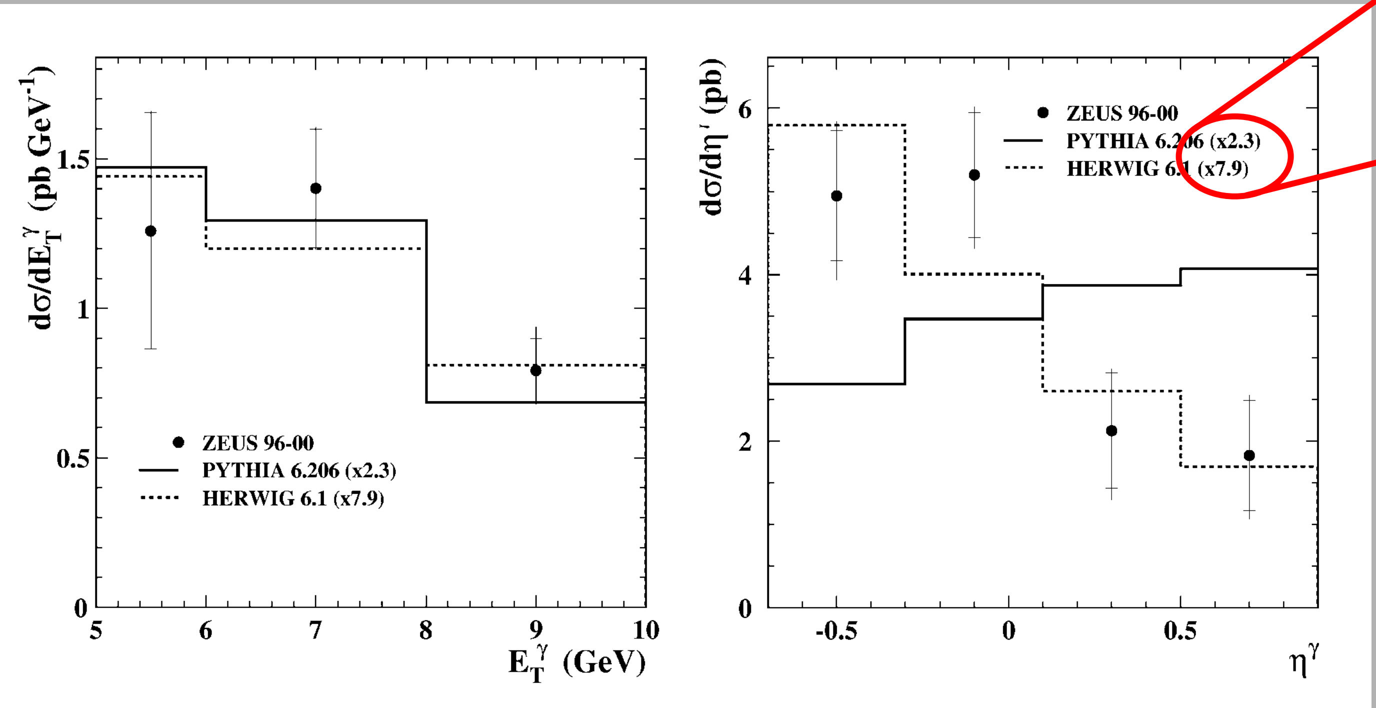
Comparison with PYTHIA and NLO pQCD (Fontannaz et al)

- PYTHIA: shape OK but normalisation low by ~50%
- NLO calculation on parton level gives good description of the data
- Variation from photon p.d.f. small compared to experimental uncertainty

Inclusive Prompt Photons in ep Deep Inelastic Scattering (HERA)

(x2.3)

(x7.9)



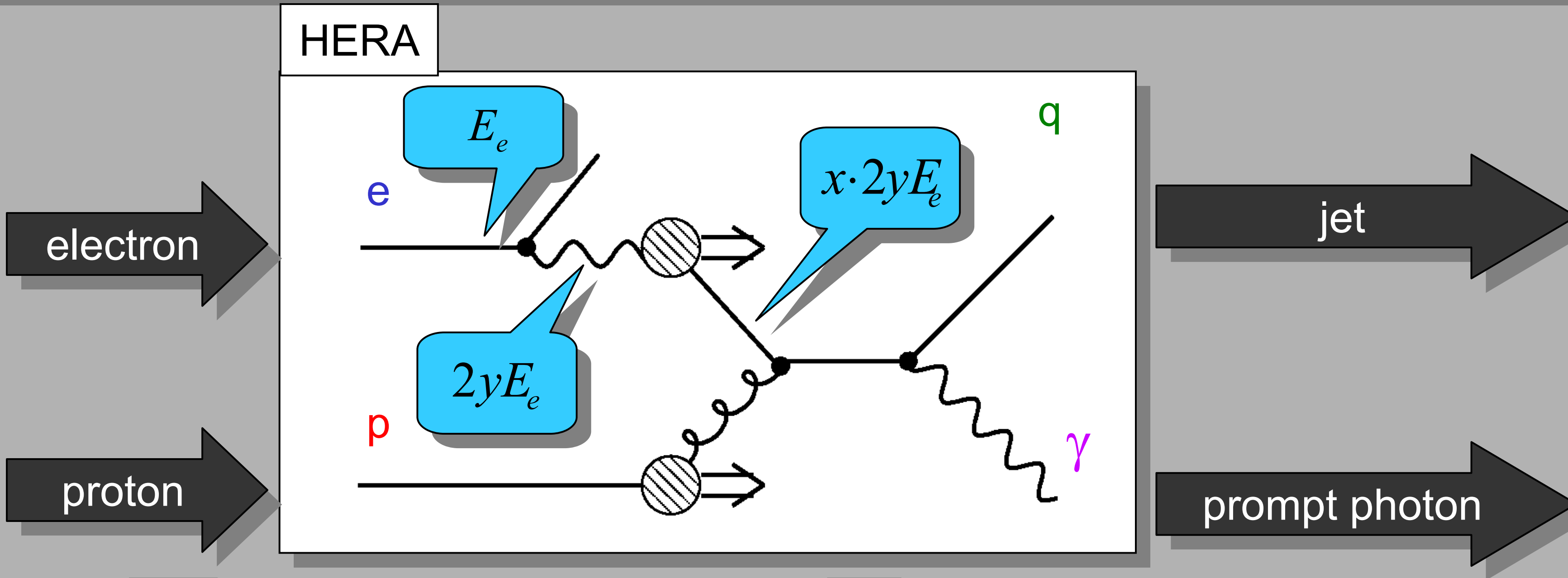
$Q^2 > 35 GeV^2$

$\mathscr{L}_{int} = 121 pb^{-1}$

Comparison with PYTHIA and HERWIG event generators

- MC lower than data by factors 2 (PYTHIA) and 8 (HERWIG)
- Shape of E_t well described, PYTHIA gives a poor description of pseudorapidity η^{γ}
- The MCs do not include wide-angle QED bremsstrahlung

Jet + Prompt Photon: a handle to direct and resolved reactions



γp

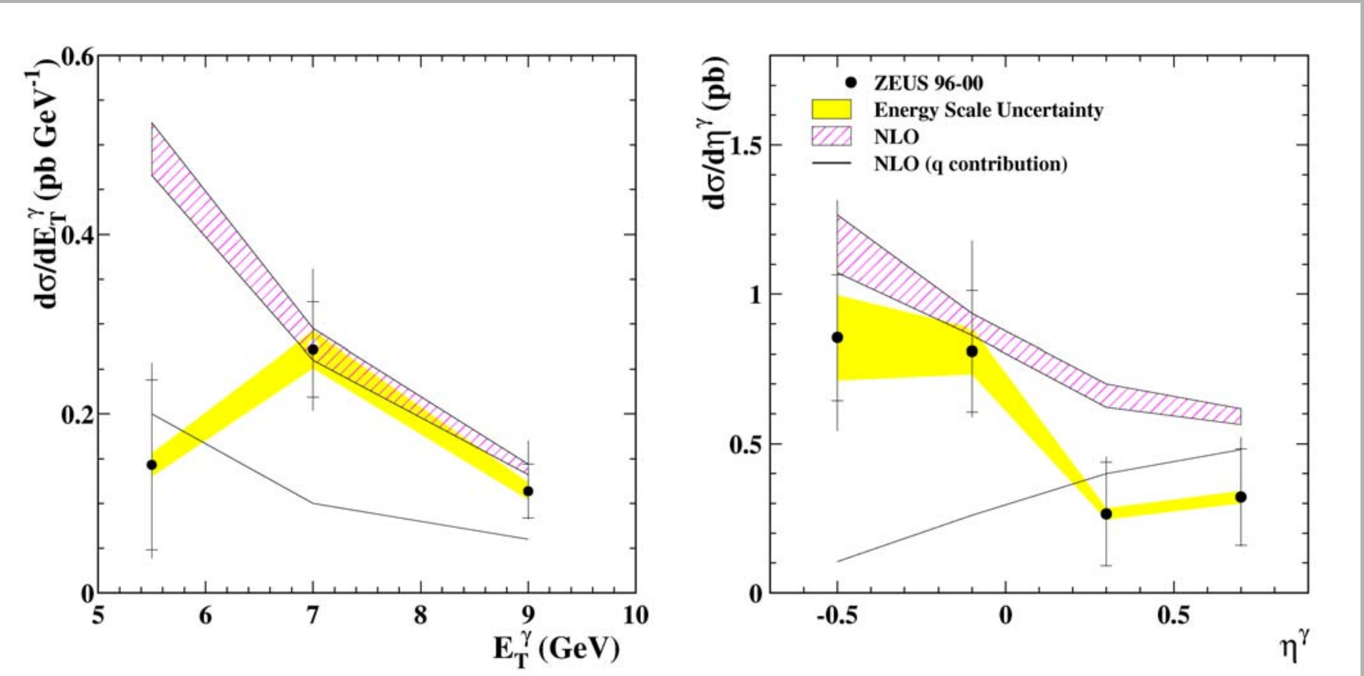
$$x_\gamma^{LO} = \frac{E_T^\gamma\left(e^{-\eta^{\text{jet}}} + e^{-\eta^\gamma}\right)}{2yE_e}$$

γγ

$$x_{LL}^{-} = \frac{p_T^\gamma\left(e^{-\eta^{\text{jet}}} + e^{-\eta^\gamma}\right)}{y^{-}\sqrt{s_{ee}}}$$

- x: Fractional part of the incoming photon energy, taking part in interaction
- Definitions are infrared safe for x -> 1
- Jet E_t does not enter the definition (but hadronic final state does via *y*)

Jet + Prompt Photon in ep Deep Inelastic Scattering (HERA)

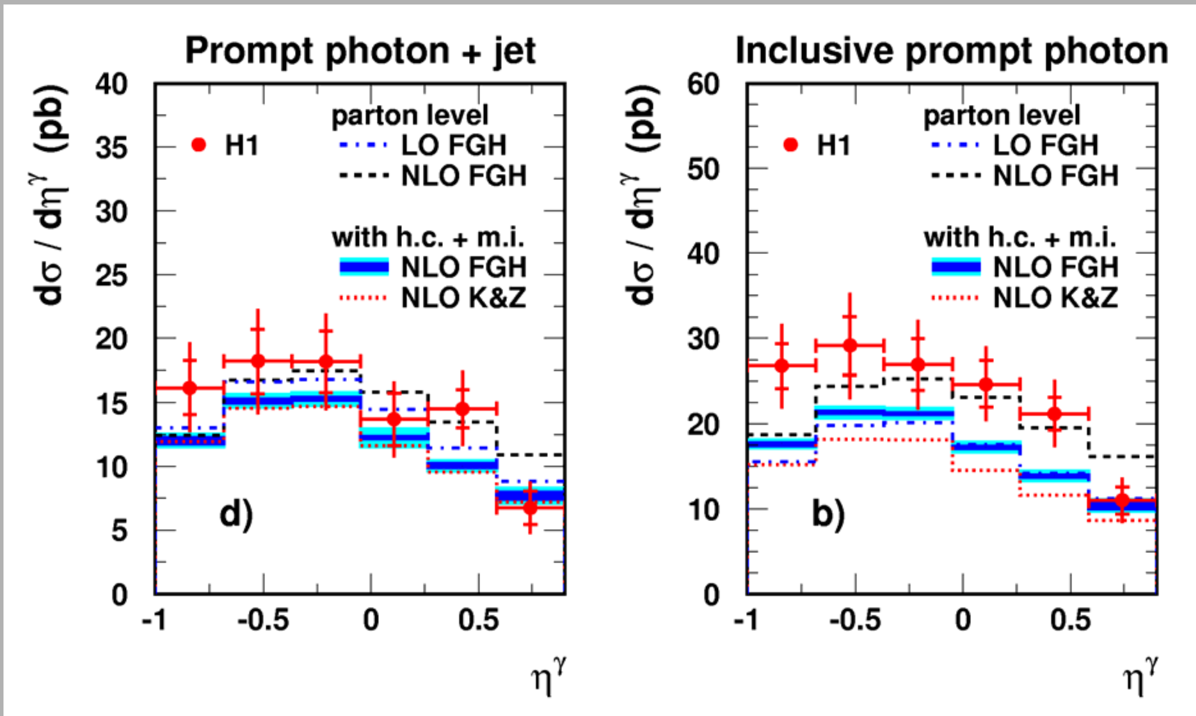


$Q^2 > 35$ GeV^2
$\mathscr{L}_{int} = 121$ pb^{-1}

Comparison with calculation to $O(\alpha^3\alpha_s^1)$ (Kramer, Spiesberger)

- NLO calculation on parton level: normalisation reasonable
  poor description at low E_t and in the more forward (proton beam) direction
- PYTHIA and HERWIG still by factors 2-4 too low (not shown)

Jet + Prompt Photon in ep Photoproduction (HERA)



$Q^2 < 1 GeV^2$

$\mathcal{L}_{int} = 105\ pb^{-1}$

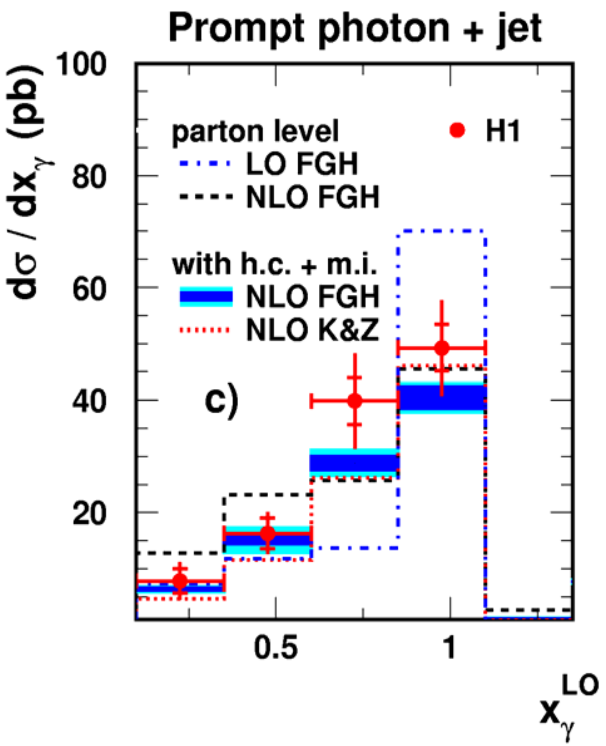
Comparison with NLO pQCD:

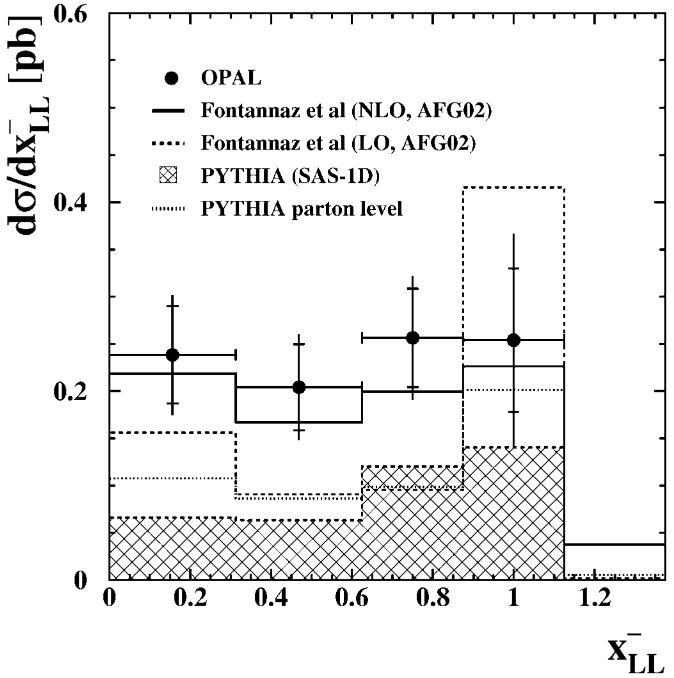
Fonatanaz, Guillet, Heinrich (FGH)

Krawczyk, Zembruski (K&Z)

- Reasonable description of the data by both NLO calculation on parton level
- If a jet is required: slightly better description, NLO/LO correction more moderate
- Corrections for hadronisation and multiple interactions, taken from PYTHIA, do not improve the description

Jet + Prompt Photon in ep Photoproduction and Photon-Photon Collisions





Photon structure enters at lower x≤0.85 (resolved contribution)

- Shape of the distributions different for HERA and LEP
- Both: NLO consistent with the data
- multiple interactions more important at low x_γ (resolved photon)

Summary

- Prompt photons: study pQCD and p.d.f. of proton and photon
- Alternative to jets:
  - ☺ no hadronisation of the photon, good energy measurement
  - ☹ small cross section, elaborate photon identification
- Consistent findings for γp,DIS (HERA) and $\gamma\,\gamma$ (LEP)
  - MC generators PYTHIA, HERWIG: always undershoot the data, shape in general OK
  - NLO QCD calculations on parton level are in reasonable agreement with the data
  - If multiple interactions and hadronisation are taken into account, the NLO calculations somewhat undershoot the data (H1)
- Why are the predictions low? Higher orders? Non-perturbative effects?
- Possible improvements of data analyses: extend phasespace, use more data (HERA II), refine π^0 supression/subtraction